Water Management Research in the Western United States - Case Study: Water Measurement and Water Systems Automation

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1.0 Summary

In order to conduct an effective applied research program on irrigation, a general organizational philosophy is applied. This approach as described by W. Edwards Deming [Walton (1986)] is used by researchers in the Water Resources Research Laboratory (WRRL). The basic plan of attack is to identify a vision for the research. In order to do this, a "needs identification" is conducted. Goals, tasks, and plans are formulated to accomplish the desired effect within the time frame and budget available. This paper will describe the research process for water measurement and automation research projects and will outline how the process applies to two field applications: Jones Hole National Fish Hatchery, in Utah, and East Bench Irrigation District, in Montana.

Water control systems and measurement technologies play a major role in a continuing effort to improve water project operations in the Western United States. Dramatic improvements are now feasible because of recent advancements in data collection, communication, measurement, and control technologies. This research promotes better and more efficient water application through development, testing, demonstration, implementation, and technology transfer. This applied research integrates control techniques to make applications more economical and more available to hundreds of projects that need to improve water management at low cost.

2.0 Vision

To create "constancy of purpose" for the research, a vision statement was developed. The vision statement is a reflection of a needs assessment and conveys the image that we would like to communicate to our customers. The needs assessment for this research is outlined in a document on the world wide web, "Water Automation Needs Survey" (Pugh 1995). For the **"Water Measurement"** and **"Water Systems Automation"** projects the vision statement is:

"Provide technical assistance to water users in the Western United States by developing and implementing new and existing technologies as a catalyst to accelerate progress in "real world" applications."

Some of Deming's points relevant to research management are:

- ***Improve constantly and forever evaluate and improve the system and the plan.*** Improvement is not a one-time effort. Researchers should continually look for ways to improve quality and re-evaluate the plans and methods.
- ***Institute training***. Many times people are trained by other workers and are not given enough information to do a good job.
- ***Drive out fear.*** Many people are afraid to ask questions. People will continue to do things the wrong way or not at all rather than asking questions.
- ***Break down barriers.*** Open up lines of communication between different departments.

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Some of Deming's "deadly sins" are:

- ***Lack of constancy of purpose*.** Without long-range plans, the management and the employees are insecure.
- ***Emphasis on short term benefits*.** Putting out "brush fires" rarely nets long-term benefits.
- ***Annual or frequent performance evaluation*.** Teamwork is destroyed, rivalry is generated.
- ***Excessive changes in project management*.** Job-hopping team leaders do not foster understanding and follow through, which is necessary for long-term improvements.

Keeping in mind the vision and points listed above, project plans were developed for the **Water Management Research** projects **"Water Measurement"** and **"Water Systems Automation**."

3.0 Overview

Agriculture accounts for the vast majority of water use in the Western United States. Although fewer new irrigation projects are being constructed now than in years past, hundreds of irrigation water delivery systems are currently in operation. Many irrigation projects must now adapt to changing priorities introduced by environmental issues and increasing demands from other competing purposes such as recreation and municipal supplies. Since new storage reservoirs are usually not an option, the existing water must be managed more precisely to meet the changing priorities. As a result, both old and new water projects must achieve a higher level of water management and water conservation than was necessary in the past.

Large delivery systems, such as the Central Arizona Project, rely heavily on Supervisory Control and Data Acquisition (SCADA) systems. However, most irrigation canal systems are still operated as they were 50 to 100 years ago. Traditional operations usually involve periodic visits the control structures to make adjustments, without the benefit of knowing what is happening in the rest of the system. Modern methods of operating irrigation canal systems can significantly improve water use efficiency, however implementation of these methods is not yet widespread on older projects. These improvements have the potential to yield both agricultural benefits and environmental benefits; increased delivery flexibility and dependability will benefit farmers and canal operators while better system management reduces water waste, maintenance costs, and negative environmental impacts. The application of modern monitoring and control technology is one of the few "new" methods available to increase agricultural water conservation. On many water projects, automation is the single option with the greatest potential for improvement in water system operations.

Research facilitates the application of control system technologies. New development work is pursued where needed, but the greatest needs involve integration of new technologies into the existing infrastructure and the culture of the water supplier (irrigation district). Many times current methods of operation are ingrained into the traditional processes. Introducing computers and remote monitoring and control can be a traumatic change for operating personnel and the governing water boards. This research emphasizes technology transfer through implementation, demonstration, and training. Applications of technologies are designed to meet specific needs on operating water projects.

Figure 1 - Canal model in Reclamation's Water Resources Research Laboratory in Denver. The 100-m-long canal is equipped with a variety of gates and instruments. The facility is used for development, demonstration, and training.

4.0 Partnerships

Implementation is carried out through collaboration with other federal and non-federal partners. WRRL staff coordinate these efforts closely with field office personnel, water district staff, and others who deal with operating water projects. Partnerships with federal and state agencies provide additional funding and "in-kind" services to help leverage limited research resources. These partnerships are also an effective means to avoid duplication of effort. Reclamation's partnerships with the Natural Resources Research Service (NRCS) and the Agricultural Research Service (ARS) are important collaborations and help disseminate the technology faster. Agreements are also in place with the United States Geological Survey (USGS), the Fish and Wildlife Service (FWS) and others. Research funding is used primarily to develop and investigate the integration of new technologies and to demonstrate and test these technologies in Reclamation's hydraulics laboratory in Denver Colorado (figure 1) and in field applications.

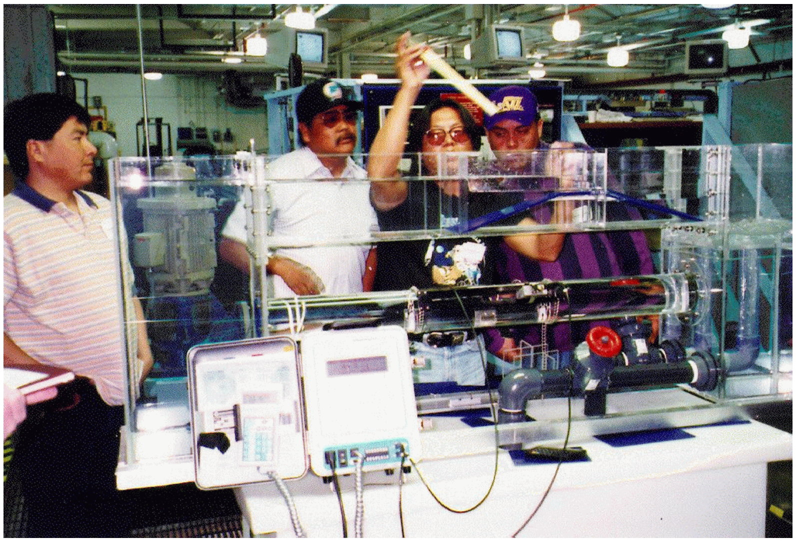

Figure 2 - Water Measurement Training at one of the "hands-on" training sessions in the WRRL Laboratory.

5.0 Goals

The primary goals of the research are:

5.1 New Development - Develop new operating methods, control techniques, control logic, data collection instrumentation, data communication systems, power systems, equipment interfaces, monitoring and control software, and control hardware. New or improved measurement methods and technologies are investigated and applications are developed. Numerical methods in computational fluid dynamics are used to develop and calibrate Parshall flumes, long-throated flumes, and other water measurement structures.

5.2 Testing - Perform laboratory and field testing of methods, equipment, and software; including products that we develop through this research, and products from commercial vendors and project cooperators.

5.3 Demonstration - Demonstrate the application, performance, reliability and feasibility of canal automation and newly improved water measurement products in the hydraulics laboratory and at field installations. Develop new demonstration enhancements for the **"Portable Water Measurement Demonstration Flume"** (Figure 2). We have built several of these flumes to assist Reclamation offices in their public education programs.

5.4 Implementation - Work with cooperators at existing projects to implement field modernization efforts. Provide technical assistance with assessment, planning, design, equipment selection, software development, installation, and follow-up for these modernization projects. Work with cooperators at existing projects to implement new flow measurement methods.

5.5 Technology transfer - Disseminate information on operation, control, and automation to water users, water district managers, canal operators, planners, and engineers.

- A **"**Flow Measurement Technology**"** world wide web site has been launched to collect and exchange information on current water measurement technologies and approaches. [http://www.usbr.gov/wrrl/fmt] The wealth of hands-on experience in Reclamation field offices and other offices can be shared through discussion and comment pages on this web site. Further development and use of this site is a part of this research.

- Training is accomplished in cooperation with Reclamation's Field Services Program. New aspects of canal automation and flow measurement technology are continually added to workshops which are presented several times a year to Reclamation personnel, water district personnel, and international clients. Custom training is also performed.

- Publications include conference papers, journal articles, monographs on automation, a Flow Measurement Handbook and a chapter in a hydraulics textbook. The Water Measurement Manual is available in hard copy and on the web site. The web version of the Water Measurement Manual is a living document and will be continually supplemented with new technologies.

7.0 Objectives and Tasks

One of the primary objectives of these programs is **Water Conservation**. In order to accomplish the objectives, the following tasks are in the project plan:

7.1 Monitoring - Develop accurate monitoring systems for water deliveries.

7.2 Provide accurate flow measurement. - Maintain accurate flow measurement at Reclamation canal deliveries and hydropower facilities. A user-friendly windows based computer program (WinFlume) has been developed in conjunction with the ARS and the International Institute for Land Reclamation and Improvement (ILRI) in the Netherlands to design and calibrate long-throated flumes and broad-crested weirs.

7.3 Provide "real-time" flow data. For use in scheduling and control of diversions and reservoir releases.

7.4 Enhance automation control algorithms.

7.5 Develop and demonstrate inexpensive, accurate agricultural flow measurement

8.0 Field Applications

Field applications serve as demonstration areas to showcase "real-world" examples of water control technologies, and to provide feedback to prospective beneficiaries and for further improvements. Most of the funding for field applications comes from cooperating projects and other funding sources such as Reclamation's Field Services Program and the irrigation districts. A critical aspect of implementation is participation of the irrigation district personnel from the start of the project. On the smaller and older projects, the implementation usually evolves. The first step is remote monitoring, this involves installation of measurement equipment with the information telemetered to a central site, usually the water district office. As the personnel become familiar and comfortable with the equipment, remote manual control of check gates can be added. The third step is automatic control, in this phase, key sites are controlled to maintain constant water levels or flows to the canals. Gradual improvements can usually be accomplished without a major monetary investment. As transition occurs, it is important for a well qualified integrator to be involved to help address problems. The WRRL researchers sometimes fill this role until the field people are comfortable with their system, and are frequently involved as consultants.

New development work also targets specific application needs. Priority is given to technical developments that meet distinct needs on collaborative projects and have potential application on other projects as well.   Most of this work falls in the category of applied research.

Technology sharing is accomplished through the production of informational video tapes, newsletter articles, technical papers, and workshop materials. Through video tape productions, basic information can be widely distributed at low cost. Technical papers and articles about specific technology advancements and implementation examples will be published in Reclamation's O&M Bulletin, conference proceedings, and professional society journals. Disseminating information to irrigators, water district staff, and Reclamation's regional and area office personnel, increases our opportunities to help water users conserve water and enhance the environment.

The following field applications are examples of the research approach described above:

8.1 Flow Measurement Technical Assistance -
Jones Hole National Fish Hatchery (JHNFH), United States FWS

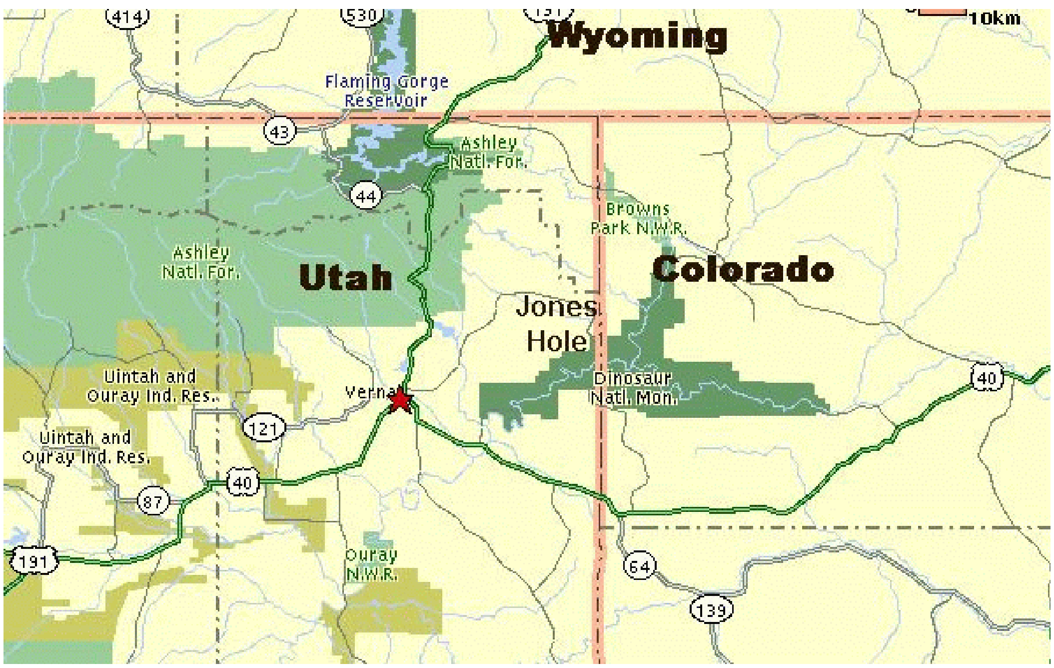

Figure 3 - Location of Jones Hole National Fish Hatchery

8.1.1 Introduction
WRRL staff were asked to evaluate the flow measurement needs at Jones Hole National Fish Hatchery near Vernal, Utah, (Figure 3). The purpose of flow measurement was to determine how much water is being collected and reused in each part of the system, and estimate the amount of water that is availableH:\HOME\CPUGH\ASCE\review summaries\Price_current_meters_review_summary.wpd. With this information, expansion of the hatchery can be evaluated to determine how many extra raceways could be added, and where to locate them.   There is a widespread problem with a parasitic disease called “whirling

Figure 4 - Jones Hole Creek and Canyon

disease" throughout trout populations in the Western United States. Some fish hatcheries actually spread the disease after the parasite has infected hatchery water. Adequate water of reasonable quality needs to be available for fish rearing. The Jones Hole NFH is preferred for expanded fish production instead of a new hatchery, since the spring fed (groundwater) source if free of whirling disease.

8.1.2 Description of the Fish Hatchery Flow System

The hatchery is about a kilometer long and 100 meters wide, It runs parallel to Jones Hole Creek (figure 4) and takes advantage of the natural drop in elevation to supply the water. Features of the hydraulic system include:

- the Jones Hole Creek bypass structure (a rectangular concrete lined channel to carry Jones Hole Creek flows around the hatchery),
- a shallow underground spring-water perforated-pipe collector system,
- diversion structures to direct flow from the collector pipe to the hatchery,
- control structures to direct flow through "first-use" pipes to the raceways and hatchery building, and to return excess flow to the collector pipe,
- the hatchery building, and raceways (where the fish are raised),
- interconnecting pipelines to deliver "first-use" water, and "re-use" water to and from the raceways,
- drains to send "used" water to the clarifier pond, where solids settle out before the flow returns to Jones Hole Creek.

8.1.3 Flow Measurement Options

Several flow measurement methods were considered during an evaluation of the project and discussions with the FWS personnel, including:

- Weirs in control structures - not enough approach, low head, and poor flow conditions
- Propeller meters - to difficult to install, maintain, expensive
- Acoustic flow meters - expensive, high maintenance, difficult to install on concrete pipes
- In-line magnetic meters - difficult to install, expensive
- Vortex shedding meters (figure 5) (the method chosen);

8.1.4 Vortex-shedding Meters

The vortex shedding meters have several advantages over other devices including:

- Wet installation, saddle on pipe with one 50mm hole with standard connection
- No moving parts, waterproof, rugged, easily removed for cleaning if needed
- Large flow range 0.10-5.0 m/s, accurate, digital output, accurate
- Relatively inexpensive
- Can be used on all types of pipe, including concrete

Access was needed to the pipes leaving each control structure to install vortex meters. This was accomplished by excavating with a backhoe and installing a concrete manhole (Figure 6). The meter was installed by drilling a hole in the pipe and attaching a pipe saddle with a standard threaded connection to accommodate the meter (Figure 5). Each meter has twenty feet of cable for connection to a digital readout to be located at or near ground level. The meters each have a ball valve and retraction/insertion crank for easy installation and removal without de-watering the pipeline. At Jones Hole the total cost of mounting apparatus and instruments was approximately $2,000 per meter. The cost of the concrete manholes, including installation, was about $40,000. The flowmeters can be battery operated with 12 Vdc or powered by a dc converter if ac power if available.

Figure 5 - Model 3100 Fluidyne Vortex Flowmeter with a digital-LED readout (flow in gallons per minute).

Figure 6 - New flow measurement manhole in the foreground and control structure number one in background.

8.1.5 Conclusions**, **Jones Hole

At Jones Hole, technical assistance was provided to assess the needs of the client, and to install instruments to make flow measurements in a closed pipe system. The client's budget was taken into account to match the best technology available with the application. The Water Measurement Research project provided expertise to help address a current environmental concern for raising fish free from "whirling disease." Follow up and continuing consultation have been provided to solve individual problems encountered during the installation phase. The application of new technology has been used as a case study for others. The details are being published at an American Society of Civil Engineers (ASCE) meeting in July (Pugh, 2000).

8.2 Water Automation and Flow Measurement Assistance - East Bench Irrigation District - Dillon, Montana

8.2.1 Introduction

East Bench is a relatively new project in Reclamation, The dam and canals were built in the 1960s. The East Bench Unit of the Pick-Sloan Missouri Basin Program is in southwestern Montana (Figure 7), along the Beaverhead River. The unit provides full irrigation service to 9000 hectares and supplemental irrigation service to 12,000 hectares. Principal features include Clark Canyon Dam and Reservoir, Barretts Diversion Dam, East Bench Canal, and a system of

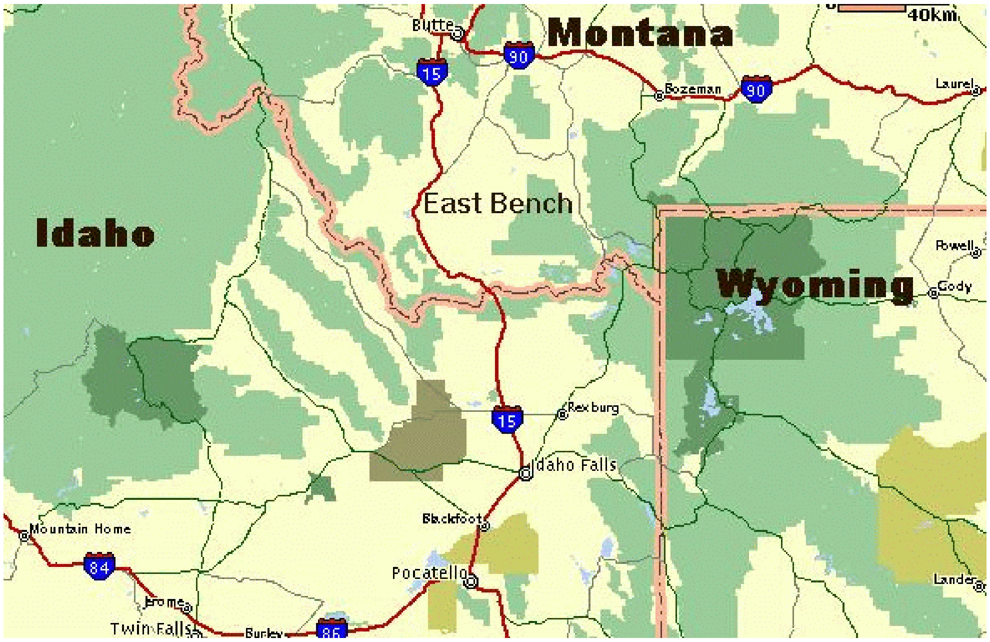

Figure 7 - Location of East Bench Irrigation District.

laterals and drains. Barretts Diversion Dam, 18 km below Clark Canyon Dam, diverts water from the Beaverhead River to the East Bench Canal and the Canyon Canal. Clark Canyon Reservoir has a total capacity of 317 million m^3, which includes an active capacity of 155 million m^3. East Bench Canal heads at Barretts Diversion Dam and runs in a northeasterly direction for 70 km (Figure 8). Initial capacity of the canal is 12.5 cubic meters per second. The original controls and telemetry at East Bench were simple water contact switches to maintain the upstream water level at Barretts Diversion Dam.

Figure 8 - Check Structure on East Bench Canal

Figure 9 - Parshall Flume at East Bench

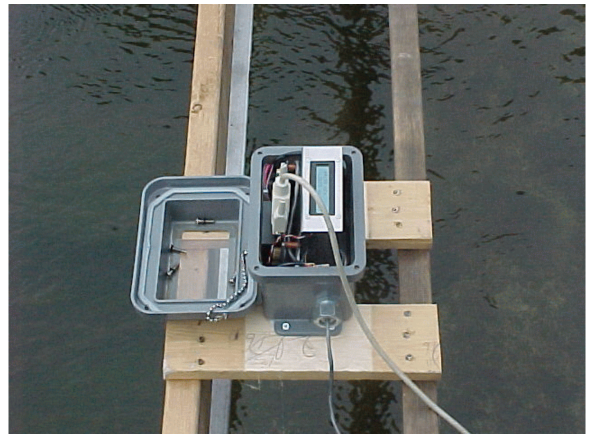

Figure 10 - Self-contained ultrasonic flow measurement recorder and data logger.

8.2.2 Field Modifications

Self contained water measurement devices (Figures 9 and 10) were installed on the East Bench Project. These devices are being evaluated in laboratory and field conditions to determine their accuracy and dependability.

Irrigation district personnel attending training in Denver at the "Modern Methods of Canal Operations Workshop" requested assistance in converting their system to remote monitoring and control. In the spring of 1999, WRRL and field personnel from United States Bureau of Reclamation assisted with equipment installations at Clark Canyon Dam, at Barretts Diversion Dam, and at three check structures. Software and hardware were also installed at the water district office. Communications are with VHF radio and cell phones.

8.2.3 Conclusions, East Bench

Consultations with Reclamation "Field Services Program" personnel and subsequent training in water measurement and modern control methods convinced irrigation project personnel to modernize their irrigation system. The process has been very successful, however a continued commitment is needed to improve the system.

9.0 General Conclusions

- **Research management needs a clear direction and constancy of purpose.**
- **After assessing needs, a vision statement helps to convey the image that we want to communicate to our customers.**
- **Continual improvement of the research processes and tasks will help to improve the quality of the results.**
- **Involvement of the beneficiaries of the research and effective technology transfer methods are very effective methods to implement the research.**
- **Leveraging of resources through partnerships amplifies the benefit of the research.**

10.0 Disclaimer

Mention of trade names should not be construed as an endorsement or recommendation of a product by the Bureau of Reclamation.

11.0 References

Walton, Mary, “The Deming Management Method,” Perigee Books, the Putnam Publishing Group, New York, New York, 1986.

Pugh, Clifford A., “Water Automation Needs Survey,” Memorandum July 27, 1995.

United States Bureau of Reclamation, “Water Measurement Manual,” Third Edition, Superintendent of Documents, US Government Printing Office, Denver 1997.

Pugh, Clifford A. and Einhellig, Robert, “Flow and Velocity Measurements Using Vortex Shedding and Magnetic Flow Meters, Jones Hole National Fish Hatchery,” 2000 ASCE Conference on Water Resources Engineering, Planning, and Management, Minneapolis, MN.